I INTERPRETATION

A Combined SM Higgs Results

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As the sections above show, there is no single search channel for the Higgs which one might call "golden"; to maximize the sensitivity of the Higgs search it is necessary to combine the results of all the channels. This section presents the results of combining all Standard Model Higgs search channels, from both experiments, in terms of the integrated luminosity needed to exclude the Higgs at 95% CL (assuming it is not there) or discover it at the 3σ or 5σ level if it is.

Statistical Method

The statistical method employed here for combining channels is discussed in the Appendix. Briefly, the result of each search channel is treated as a counting experiment, and for a given outcome there is some Poisson probability. For all channels in both experiments, these probabilities are multipled together to form a joint likelihood. This likelihood can be expressed as a function of the Higgs signal cross section, and can be used to set 95% CL limits or discovery significances. To take into account all possible experimental outcomes, the integrated luminosity threshold quoted below represent those values for which the desired statistical threshold is met in 50% of of all possible outcomes.

Overview of results

The results of all the channels studied are summarized in Tables 1 and 2. The tables show the expected signal S, the expected background B, and the sensitivity $S/\sqrt{B}$ in each channel as a function of the assumed Higgs mass. In all the low-mass channels, we have taken the numbers from assuming a 10% resolution in $m_{b\bar{b}}$.

The tables indicate that of the low mass channels, the $\ell\nu b\bar{b}$ and $\nu\bar{\nu}b\bar{b}$ have the most sensitivity. Also, while the dilepton mode adds significantly to the sensitivity, the all-hadronic channel brings little information to the final combination.

In comparing the different analyses, it is clear that the neural network technique results in significantly enhanced sensitivity in the three channels where it has been studied. Note that the NN- and SHW-based channel analyses do not take into account trigger inefficiency for events which otherwise pass the selection; this should be no problem in the $\ell\nu b\bar{b}$ and $\ell^+\ell^- b\bar{b}$ cases but may be a slight overestimate at low masses in the $\nu\bar{\nu}b\bar{b}$ case.

For the high-mass channels, the $\ell^+\ell^-\nu\bar{\nu}$ channel has the most sensitivity, whilst the $\ell^\pm\ell^\pm jj$ channel has nearly as good sensitivity over a broader mass range. The $\ell^\pm\ell'^\pm\ell^\mp$ channel has competetive sensitivity, but with its very low expected signal it contributes significantly only at the highest integrated luminosities.[1]

Combined channel integrated luminosity thresholds

We perform determinations of the integrated luminosity thresholds combining all low-mass and high-mass channels. In the combination we assume that both experiments' is used by doubling each channel: we generate separate pseodoexperimental outcomes for each channel in each experiment, and combine all the results together in the final likelihood.

To take into account reasonable systematic errors, we incorporate into the likelihood a relative uncertainty on the background for each channel which is the smaller of 10% of the expected background or $1/\sqrt{LB}$, where L is the integrated luminosity and B is the expected number of background events in 1 fb^{-1}. Such an assumption is typical of the level of uncertainty experienced in new particle searches at colliders. Note that if one does not let the systematic error decrease with integrated luminosity, numerical instability can result. More importantly, in the real experiments as the integrated luminosity increases the experimenters will have better control of the systematic errors, and will in all likelihood harden the selection criteria to improve the sensitivity while maintaining tolerable systematic uncertainties.

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[1] This underscores dramatically the need to use true Poisson statistics rather than a Gaussian approximation!

channel	rate	Higgs mass (GeV/c^2) 90	100	110	120	130
$\ell\nu b\bar{b}$ (CDF)	S	8.4	6.6	5.0	3.7	2.2
	B	48	52	48	49	42
	$S/\sqrt{B}$	1.2	0.9	0.7	0.5	0.3
$\ell\nu b\bar{b}$ (SHW)	S	10	8	5	4	3
	B	75	68	57	58	52
	$S/\sqrt{B}$	1.1	1.0	0.7	0.5	0.4
$\ell\nu b\bar{b}$ (NN)	S	8.7	9.0	4.8	4.4	3.7
	B	28	39	19	26	46
	$S/\sqrt{B}$	1.6	1.4	1.1	0.9	0.5
$\nu\bar{\nu}b\bar{b}$ (CDF)	S	2.5	2.2	1.9	1.2	0.6
	B	10.0	9.3	8.0	6.5	4.8
	$S/\sqrt{B}$	0.8	0.7	0.7	0.5	0.3
$\nu\bar{\nu}b\bar{b}$ (SHW)	S	8.9	6.7	4.6	3.2	2.1
	B	56	52	48	45	41
	$S/\sqrt{B}$	1.2	0.9	0.7	0.5	0.3
$\nu\bar{\nu}b\bar{b}$ (NN)	S	11	7	5.3	3.7	2.6
	B	54	30	24	20	21
	$S/\sqrt{B}$	1.5	1.3	1.1	0.8	0.6
$\ell^+\ell^-b\bar{b}$ (CDF)	S	1.0	0.9	0.8	0.5	0.3
	B	3.6	3.1	2.5	1.8	1.1
	$S/\sqrt{B}$	0.5	0.5	0.5	0.4	0.3
$\ell^+\ell^-b\bar{b}$ (SHW)	S	1.5	1.2	0.9	0.6	0.4
	B	4.9	4.3	3.2	2.3	1.9
	$S/\sqrt{B}$	0.7	0.6	0.5	0.4	0.3
$\ell^+\ell^-b\bar{b}$ (NN)	S	1.2	0.8	0.5	0.5	0.3
	B	4.2	2.7	2.3	2.0	1.9
	$S/\sqrt{B}$	0.6	0.5	0.3	0.3	0.2
$q\bar{q}b\bar{b}$ (SHW)	S	8.1	5.6	3.5	2.5	1.3
	B	6800	3600	2800	2300	2000
	$S/\sqrt{B}$	0.10	0.09	0.07	0.05	0.03

TABLE 1. Summary of low-mass Standard Model Higgs search channel sensitivities used in the combined integrated luminosity threshold calculations. The values of S and B are expressed as the number of events expected in 1 fb^{-1}, and $S/\sqrt{B}$ is a pure number. Here we assume an improved Run 2 $m_{b\bar{b}}$ resolution of 10%. "SHW" indicates the analyses based on the SHW simulation, "NN" indicates the SHW neural-network-based analyses, and "CDF" indicates the analyses based on extrapolations from the CDF Run 1 conditions to Run 2 detector geomentry and efficiencies.

channel	rate	Higgs mass (GeV/c^2) 120	130	140	150	160	170	180
$\ell^\pm\ell'^\pm\ell^\mp$	S	0.011	0.025	0.039	0.050	0.057	0.033	0.033
	B	0.025	0.025	0.025	0.025	0.025	0.025	0.025
	$S/\sqrt{B}$	0.07	0.16	0.25	0.32	0.36	0.21	0.21
$\ell^+\ell^-\nu\bar{\nu}$	S	-	-	2.6	2.8	1.5	1.1	1.0
	B	-	-	44	30	4.4	2.4	3.8
	$S/\sqrt{B}$	-	-	0.39	0.51	0.71	0.71	0.51
$\ell^\pm\ell^\pm jj$	S	0.08	0.15	0.29	0.36	0.41	0.38	0.26
	B	0.58	0.58	0.58	0.58	0.58	0.58	0.58
	$S/\sqrt{B}$	0.11	0.20	0.38	0.47	0.54	0.50	0.34

TABLE 2. Summary of high-mass Standard Model Higgs search channel sensitivities; all results are based on SHW studies. The values of S and B are expressed as the number of events expected in 1 fb^{-1}, and $S/\sqrt{B}$ is a pure number.

Without the inclusion of these systematic errors, the integrated luminosity thresholds are approximately 30-50

Figures 1 and 2 show the integrated luminosity required to either exclude the SM Higgs at 95% CL or discover it at the 3σ or 5σ level of significance, as a function of Higgs mass, for the SHW analyses with and without the neural net selection. The integrated luminosity in the plot is the delivered integrated luminosity per experiment, but the result is the combination of both experiments. (The thresholds for a single experiment are very close to a factor of two higher.)

As the plots show, the required integrated luminosity increases rapidly with Higgs mass to 140 GeV/c^2, beyond which the high-mass channels play a domminant role. In Run 1 (2 fb$^-$1) the 95% CL limits will barely extend the expected LEP-II limits, but with 10 fb^{-1} in Run 3, the SM Higg can be excluded up to 190 GeV/c^2 if it does not exist in that mass range.

In Run 3, if a SM Higgs exists with mass less than 180 GeV/c^2, the combined sensitivity of CDF and DØ will yield an observation at the 3σ level up to 180 GeV/c^2 mass with 20 fb^{-1}. However, a 5σ discovery does not appear possible below just under 120 GeV/c^2.

Of course, breakthroughs in technique are always possible, and have indeed been the norm in the past. For example both the Higgs search in LEP-I and the top quark search in Run 1 at the Tevatron exceeded the expectations of studies prior to machine turn-on. The studies presented here should be taken as cautiously optimistic: Using full mass spectrum fits, using neural network techniques, improvements to the trigger efficiencies, the addition of other channels (tau decay modes, single Higgs production) and improvements to the mass resolution and tagging effiency beyond that projected here may all serve to dramatically improve the discovery potential for the Higgs at the Tevatron.

REFERENCES

1. The program can be found at the Web site http://www.physics.rutgers.edu/ jconway/soft/stat/stat.html

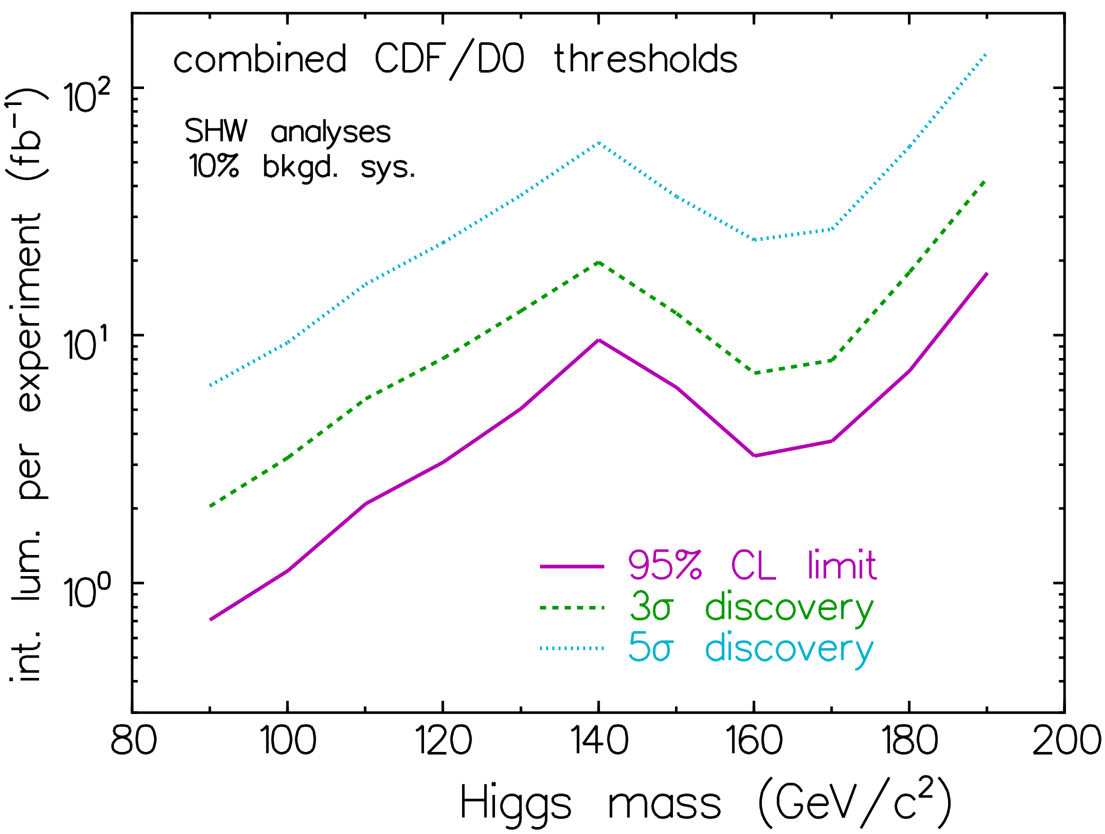

FIGURE 1. Integrated luminosity delivered per experiment required to either exclude the SM Higgs at 95% CL or discover it at the 3σ or 5σ level, as a function og Higgs mass. This represents the combination of all the SHW-based channels, combining the statistical power of both experiments.

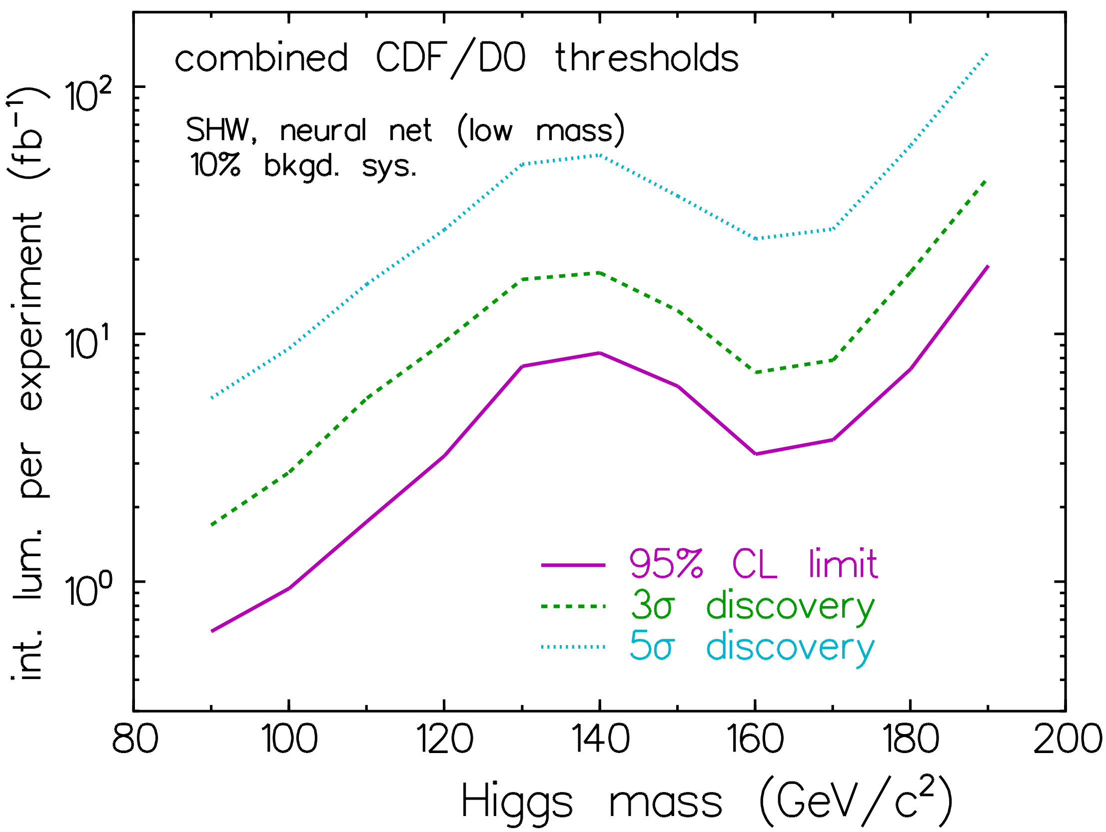

FIGURE 2. Integrated luminosity delivered per experiment required to either exclude the SM Higgs at 95% CL or discover it at the 3σ or 5σ level, as a function og Higgs mass. This represents the combination of all the SHW-based channels, using the neural network selection for the $\ell\nu b\bar{b}$, $\nu\bar{\nu}b\bar{b}$, and $\ell^+\ell^- b\bar{b}$ channels, and combining the statistical power of both experiments.